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Natural enemy fauna (Insecta, Araneae) found on native sagebrush steppe plants in eastern Washington with reference to species also found in adjacent apple and pear orchards

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Abstract. Seven native plants (four shrubs, two perennial herbs, and a woody vine) common in sagebrush steppe habitats of eastern Washington were sampled for predatory and parasitic arthropods. Sagebrush steppe is a common natural habitat adjacent to apple and pear orchards in that part of the state. Many predatory arthropod species found on the native plants also occur in adjacent orchards; some of these species were particularly abundant on the plants when they were flowering. Other species found on the native plants rarely occur in adjacent orchards. *Orius tristicolor* (White, 1879) was the most abundant of the natural enemies that also occur in orchards. Other predatory Hemiptera also found in adjacent orchards included *Deraeocoris brevis* (Uhler, 1904), *Nabis alternatus* Parshley, 1922, and *Geocoris* spp. Coccinellidae, Chrysopidae, and Hemerobiidae were not common on the native plants, but one or more species in each family that commonly occur in orchards were collected. Spiders found on the native plants that also occur in orchards included *Misumenops lepidus* (Thorell, 1877), *Xysticus cunctator* Thorell, 1877, *Sassacus papenhoei* Peckham & Peckham, 1895, *Phidippus* spp., *Oxyopes scalaris* Hentz, 1845, and *Meioneta fillmorana* (Chamberlin, 1919). Parasitoids, almost all of which were Hymenoptera, were collected on all plants, but species of known importance in orchard biocontrol were not found.

Key Words. Araneae, Coleoptera, Diptera, Hemiptera, Hymenoptera, Neuroptera, sagebrush steppe, natural enemies, predators, parasitoids.

INTRODUCTION

One goal of integrated pest management in tree fruits and other crops is to make better use of natural enemies for control of arthropod pests (Pedigo 1999). Consequently, ways to enhance natural enemy populations have been explored. Modifications of the crop environment using cover crops, weed strips, reduced tillage, and mulches have been shown to benefit predatory and parasitic insects and spiders (Prokopy 1994, Bugg & Waddington 1994, Sunderland & Samu 2000). However, natural enemies found in the crop environment are still subject to the disruptive effects of pesticides, cultural practices, harvest, and preparation of the field for the following year.

Undisturbed native habitat occurring adjacent to crop fields often supports natural enemies that are also found in the crop where they may contribute to biological control of pest arthropods (Miliczky & Horton 2005). The non-crop habitat may provide resources for natural enemies of crop pests that are in limited supply in the crop such as alternate prey or hosts, nectar, and water, and refugia for mating, oviposition, and overwintering (van Emden 1965, Sotherton 1984, Letourneau 1998). Habitat outside of a crop may act as a source of natural enemies

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that move into the crop and augment existing numbers, or allow natural enemies to more quickly repopulate the crop following extinction (Duelli et al. 1990, Olszak 1991, Ekbom et al. 2000). Advantages of having these habitats next to the crop ecosystem are that they generally are little affected by disruptions applied to the crop and require little or no management on the part of the grower.

The most common native habitat adjacent to orchards in eastern Washington is sagebrush steppe. Sagebrush steppe includes a number of habitat sub-types that differ in plant composition depending on soil conditions and other factors, but all sub-types are characterized by plants adapted to low rainfall typical for this part of the state (Taylor 1992). The dry steppe habitat presents a marked contrast to adjacent orchards which receive water in the form of irrigation throughout the growing season. Shrubs such as sagebrush, *Artemisia* spp. (Asteraceae), rabbitbrush, *Chrysothamnus* spp. (Asteraceae), and bitterbrush, *Purshia tridentata* (Pursh) (Rosaceae) are widespread, while annual and perennial forbs often occur in considerable variety (Taylor 1992). The arthropod fauna of sagebrush steppe thus represents one important species pool from which natural enemies colonizing adjacent orchards are potentially drawn (Rathman & Brunner 1988).

In this study we documented the natural enemy faunas (spiders, predaceous insects, and parasitic insects) of seven common native sagebrush steppe plants. Our objective was to determine whether spiders and predatory and parasitic insects known to occur in central Washington orchards (Miliczky et al. 2000, Miliczky & Horton 2005, unpublished data) also inhabit sagebrush steppe plants. Many natural enemy species found in the orchards are known to utilize orchard pests as prey or hosts, and others are presumed to do so. Natural enemies found in the orchard and in nearby sagebrush steppe are presumed to move between them (Miliczky & Horton 2005), and the sagebrush steppe may act as a source of natural enemy colonists for the orchard.

Materials and Methods

Plant species. Seven native plants that are common to dominant components of the sagebrush steppe flora in south-central Washington were studied. *Artemisia tridentata* Nutt. (Asteraceae), *P. tridentata, Chrysothamnus viscidiflorus* (Hook.) Nutt. (Asteraceae), and *Chrysothamnus nauseosus* (Pall.) Britt (Asteraceae) are shrubs, *Clematis ligusticifolia* Nutt. (Ranunculaceae) is a woody vine, and *Achillea millefolium* L. (Asteraceae) and *Eriogonum elatum* Dougl. ex Benth. (Polygonaceae) are perennial herbs. All are xeric-adapted and well-suited to the cold-desert conditions of south-central Washington. Plants were chosen for study based on a survey of natural enemies on 45 species of native and introduced plants (Miliczky & Horton 2005) which showed that these species had diverse and/or abundant natural enemy faunas.

Study sites. Sample locations were tracts of sagebrush steppe habitat adjacent to commercial, or in one case experimental, apple and pear orchards. All of the orchards had been sampled for natural enemies in previous years (Miliczky et al. 2000, Miliczky & Horton 2005, unpublished data), and their arthropod faunas are well-known. The majority of native plant samples were collected at eight sites in Yakima County, with a few samples collected at a site in Grant County, and a site in Chelan County.

Sampling methods and sampling regimes. Samples were taken with a canvas beating tray having an area of 0.45 m^2 (Bioquip products, Gardena, CA). We used the beating tray because it is a widely used collecting tool that works well for many arthropods and is suitable for use on plants of various growth forms. The method is not without bias and certain arthropods may be under-represented in beating tray samples (especially very small or very active species or those that cling tightly to the plant or that reside within a retreat). Specimens were dislodged by vigorously shaking one or more flowering stems or sharply striking a branch with a heavy rubber hose over the tray. Sample size was ten plants of a species on a given date, and we attempted to collect all natural enemies that fell onto the tray. A representative sample of the principal plant-feeding insects found on a species was also collected.

Most specimens were collected with an aspirator and promptly preserved in 70% isopropyl alcohol for later identification. Selected immature spiders were collected alive and reared to obtain positive species identification. Spiders were reared in Petri dishes or 34 ml plastic cups with tight-fitting lids and provided with water and insect prey of an appropriate size obtained from the field or laboratory cultures. A total of 189 spiders representing 13 species was reared to adulthood.

Each plant species was sampled at two or more locations, except *C. ligusticifolia* which was sampled at one site only. Sampling was done from May to October in 2002 and 2003. Miliczky & Horton (2005) indicated that natural enemies were generally more abundant on the native plants while the plants were flowering than during the pre-flowering and post-flowering periods. Therefore, in 2002 shrubs were sampled weekly during flowering with one or more additional samples taken immediately preceding and following the flowering period. *Achillea millefolium* and *E. elatum* were sampled only while they were in flower. Both plant species have a recumbent growth form except during flowering when flowering stems are available. A similar sampling regime was followed in 2003 except that *A. tridentata* and *P. tridentata* were sampled once per month from May to October and weekly during their flowering periods.

Identification of natural enemies. Spiders were identified using published keys (Roth 1993, Edwards 2004, Dondale & Redner 1978, Maddison 1996, Schick 1965, Griswold 1987) and by comparison with previously identified specimens in a reference collection. Insects were also identified using published keys or pictorial references (Gordon 1985, Goulet & Huber 1993, Flint & Dreistadt 1998). All specimens collected during the study are retained at the Yakima Agricultural Research Laboratory, Wapato, WA. Data are presented as the total number of specimens in a taxon that was collected on a plant species during the study; for example, the total number of *Deraeocoris brevis* collected on *P. tridentata* or the total number of spiders in the family Salticidae collected on *C. nauseosus*. Statistical comparisons of natural enemy faunas across plant species were not made because plant species differ in growth form (affecting in unknown ways the efficiency of the beating tray method), and because sampling effort (numbers of collections or sample sites) varied among plant species. Natural enemies were classified as species either commonly found in local orchards or of rare or incidental occurrence in local orchards based on Miliczky et al. (2000), Miliczky & Horton (2005), and unpublished data.

Results

Predatory arthropod summary

The natural enemy fauna of each plant species included many predator species that also occur in adjacent orchards, and a high percentage of the specimens collected on each plant species were species also found in orchards (Fig. 1; the figure excludes data for *Orius tristicolor* (White, 1879) due to its great abundance on some plant species). We base this conclusion on extensive previous collecting in orchards adjacent to the study sites and in other local orchards (Miliczky et al. 2000; Miliczky & Horton 2005; unpublished data). Information on individual predator species (including *O. tristicolor*) is presented in the text below and in Tables 1 and 2.

Purshia tridentata

Bitterbrush was the first species to flower and was in bloom throughout May both years (Fig. 2). A diverse natural enemy fauna was associated with *Purshia* and 1,348 predators were collected (Tables 1 and 2). Overall, 62% of the predatory arthropods collected on bitterbrush represented species also found in nearby orchards. Seventeen spider species were identified from bitterbrush, the most abundant of which was *Sassacus papenhoei* Peckham & Peckham, 1895 (Salticidae). Other common spiders were *Misumenops lepidus* (Thorell, 1877) (Thomisidae), *Oxyopes scalaris* Hentz, 1845 (Oxyopidae), and *Meioneta fillmorana* (Chamberlin, 1919) (Linyphiidae). Predatory Hemiptera in six families were found on *Purshia* (Table 2), of which the most abundant species was *Anthocoris whitei* Reuter, 1884. *Orius tristicolor* was present throughout the season but was most abundant late in the year. Coccinellidae and Neuroptera were poorly represented. Adult soft-winged flower beetles (Melyridae) were present in May and adult snakeflies (Raphidiidae) were common in May and June. Potential prey taxa found on bitterbrush included Psyllidae, Aphididae, Cicadellidae, Miridae, Tingidae, Pentatomidae, and the western flower thrips *Frankliniella occidentalis* (Pergande, 1895).

Achillea millefolium

Yarrow is a perennial herb that flowered between late May and early July (Fig. 2). Predators collected on *Achillea* numbered 1,385, of which the majority (98%) was species also found in nearby orchards. *Xysticus* and *Misumenops* spiders (Thomisidae) were abundant on *Achillea* (Table 1). Twenty-five of 27 *Xysticus* spiderlings reared to adulthood were *Xysticus cunctator* Thorell, 1877, indicating that a majority of the small, immature *Xysticus* found on the plant was probably this species. Adult *Misumenops lepidus* were common early in the flowering period, while the numerous small juveniles found during the latter half of bloom were likely also this species. *Orius tristicolor* comprised 75% of the predatory arthropods collected on *Achillea* (Table 2). Adults dominated in the early collections, and nymphs increased in number as flowering progressed. All five nymphal instars were collected, indicating that the species probably reproduces on the plant. The western flower thrips was the most abundant potential prey species on yarrow. Aphididae, Miridae, Pentatomidae, a large psyllid, and small Coleoptera were also common.

Clematis ligusticifolia

Western clematis, or virgin's bower, is a common species in dry, eastern Washington habitats. A woody, often climbing vine, our sampled plants grew along

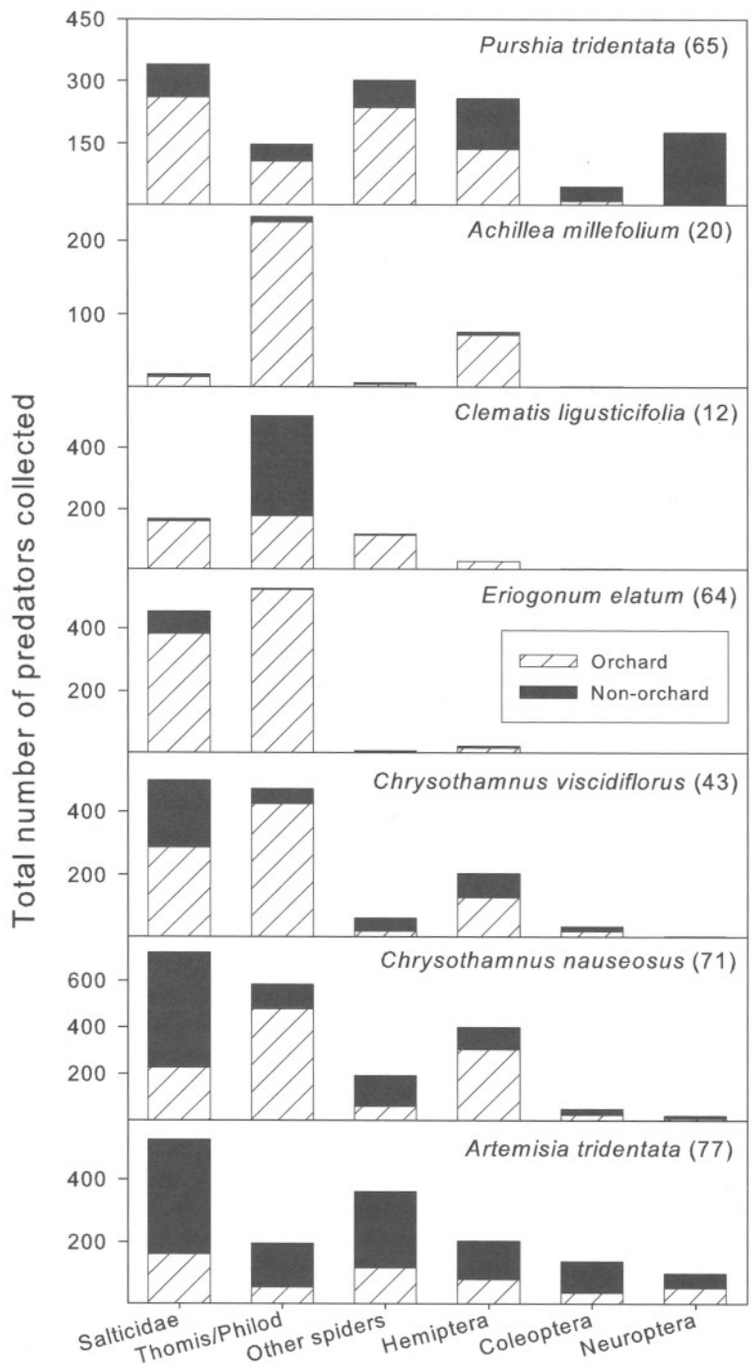

Figure 1. Total numbers of orchard-associated and non-orchard associated predators in six taxa or groups of taxa (three of spiders and three of insects) collected on the seven plants in 2002 and 2003. Note that scales differ for the different plant species. Number of collections on each plant is shown in parentheses. Thomis/Philo = spider families Thomisidae and Philodromidae. Data for *Orius tristicolor*, not included here, is presented in Table 2.

Table 1. Spiders collected on seven sagebrush steppe plants. Family totals are shown in bold when represented by more than one species. Species followed by an * are probably represented by a majority of the congeneric immatures based on identified adults from this study and previous collecting. Orchard abundance ratings are based on Miliczky et al. 2000 and Miliczky & Horton 2005. A = species abundant in some local orchards or at certain times during the season. C = species regularly found in local orchards but in lower numbers than "A" species. U = species uncommon in local orchards; of less regular occurrence than "C" species. R = species rare or incidental in local orchards: many "R" species may be largely restricted to the sagebrush steppe habitat.

Spider taxa	*Purshia*	*Achillea*	*Clematis*	*Eriogonum*	*C. viscidiflorus*	*C. nauseosus*	*Artemisia*	Orchard abundance
Sassacus papenhoei Peckham & Peckham, 1895	212	8	35	317	260	132	137	C
Sassacus vitis (Cockerell, 1894)			30			2		U
Phidippus audax (Hentz, 1845)			21					U
Phidippus johnsoni (Peckham & Peckham, 1883)	1	2	1	16				U
Phidippus comatus Peckham & Peckham, 1901		1						U
Phidippus clarus Keyserling, 1885			1					U
Phidippus immatures	43	5	72	50	27	94	23	
Pelegrina helenae (Banks, 1921)*	4				1	23	24	R
Pelegrina clemata (Levi & Levi, 1951)*	8					1	4	R
Pelegrina aeneola (Curtis, 1892)	5							A
Pelegrina immatures	59	4	8	70	196	448	325	
Habronattus hirsutus (Peckham & Peckham, 1888)*	2					1	6	R
Habronattus immatures	6		1	2	17	24	9	
Salticus scenicus (Clerck, 1757)							1	U
Total Salticidae	**340**	**20**	**169**	**455**	**501**	**723**	**528**	
Xysticus cunctator Thorell, 1877*	12	25		22	1	7	3	C
Xysticus gulosus Keyserling, 1880						3		R
Xysticus montanensis Keyserling, 1887		2			1	1		R
Xysticus locuples Keyserling, 1880	1							R
Xysticus sp.				1				
Xysticus immatures	30	143	8	127	8	6	16	
Misumenops lepidus (Thorell, 1877)*	7	21	1	19	12	38	6	C
Misumenops importunus (Keyserling, 1881)	3				3			R
Misumenops immatures	57	36	157	356	404	383	26	
Total Thomisidae	**110**	**227**	**166**	**525**	**429**	**438**	**51**	
Philodromus histrio (Latreille, 1819)	6				39	95	125	R

Table 1. Continued.

Spider taxa	*Purshia*	*Achillea*	*Clematis*	*Eriogonum*	*C. viscidiflorus*	*C. nauseosus*	*Artemisia*	Orchard abundance
Philodromus insperatus Schick, 1965			321				1	R
Philodromus immatures	14	4	4	2	4	8	19	
Tibellus oblongus (Walckenaer, 1802)*							1	C
Tibellus maritimus (Menge, 1875)						1		R
Tibellus immatures			12	1	1	40	2	
Ebo parabolis Schick, 1965	18							R
Ebo immatures			2	1		4		
Total Philodromidae	**38**	**4**	**339**	**4**	**44**	**148**	**148**	
Meioneta fillmorana (Chamberlin, 1919)	173	2	1			4	46	A
Erigone dentosa O. P.-Cambridge, 1894	1		2		1	2	2	C
Spirembolus mundus Chamberlin & Ivie, 1933				1				U
Total Linyphiidae	**174**	**2**	**3**	**1**	**1**	**6**	**48**	
Anyphaena pacifica (Banks, 1896)*	1					1		U
Anyphaena californica (Banks, 1904)	1							R
Anyphaena immatures	13	2	1	3	4	18	13	
Total Anyphaenidae	**15**	**2**	**1**	**3**	**4**	**19**	**12**	
Theridion neomexicanum Banks, 1901	5	1			1		3	C
Theridion immatures	27			2	1	4	25	
Total Theridiidae	**32**	**1**		**2**	**2**	**4**	**28**	
Emblyna shoshonea (Chamberlin & Gertsch, 1958)						123	214	R
Dictynidae – unidentified	27	2	4		41			
Total Dictynidae	**27**	**2**	**4**		**41**	**123**	**214**	
Oxyopes scalaris Hentz, 1845	42	1	108	1	14	23	34	A
Cheiracanthium mildei L. Koch, 1864			4					C
Tetragnatha immatures	1					1	2	C
Hololena immatures						13	17	U
Mimetus hesperus Chamberlin, 1923						2	6	R
Sergiolus immatures						1		R
Araneidae	7					2	1	
Family unknown	4	1						

the sloping side of an irrigation ditch next to a pear orchard. Much of the stand received irrigation overspray and was the only sample location that received supplemental water. *Clematis* had a lengthy flowering period at this site in 2002 (Fig. 2). A total of 1,156 predators was collected, of which 70% were species also

Table 2. Predatory insects collected on seven sagebrush steppe plants. Orchard abundance ratings based on Miliczky & Horton (2005) and unpublished data. A = species abundant in some local orchards or at certain times during the season. C = species regularly found in local orchards but in lower numbers than "A" species. U = species uncommon in local orchards; of less regular occurrence than "C" species. R = species rare or incidental in local orchards: many "R" species may be largely restricted to the sagebrush steppe habitat.

Insect taxa	*Purshia*	*Achillea*	*Clematis*	*Eriogonum*	*C. viscidiflorus*	*C.nauseosus*	*Artemisia*	Orchard abundance
Deraeocoris brevis (Uhler, 1904)	13		8			9	9	A
Deraeocoris bakeri Knight, 1921	1				9	14	16	R
Deraeocoris immatures	76			1	28		83	
Campylomma verbasci (Meyer-Dur, 1843)	3	49	13	8		10	21	C
Geocoris spp.	38	19	10	9	117	248	18	C
Nabis alternatus Parshley, 1922	6	5			10	36	31	C
Orius tristicolor (White, 1879)	78	1,044	319	8,138	1,398	3,417	422	C
Anthocoris whitei Reuter, 1884	110							R
Anthocoris tomentosus Pericart, 1971						1		C
Reduviidae	6	4			5	75	24	R
Phymatidae	5		1	5	35	8		R
Coccinella septempunctata (L., 1758)	1					4	1	C
Coccinella transversoguttata richardsoni Brown, 1962			2			5	8	C
Coccinella novemnotata Herbst, 1793						3	2	U
Hippodamia convergens Guerin, 1842					1	7		C
Hippodamia apicalis Casey, 1899	6				12	3	23	C
Stethorus picipes Casey, 1899	3				6	2	3	C
Coccinellidae unidentified	4	1	6		14	26	87	
Melyridae	31	1			1		7	R
Cleridae	6				2	1	6	R
Chrysopa coloradensis Banks, 1895						5	29	C
Chrysopa nigricornis Burmeister, 1839						4	16	C
Chrysopidae unidentified	1			1		2	4	
Hemerobius ovalis Carpenter, 1940			1					C
Hemerobiidae unidentified	3				2	1	7	
Coniopterygidae	4				1	9	7	R
Raphidiidae	168	1			1	1	35	R
Syrphidae			2	1		1	3	C

found in orchards. The spider fauna included a number of species not often collected on the other steppe plants (Table 1). Three *Phidippus* species (Salticidae) were collected on *Clematis*, of which *Phidippus audax* (Hentz, 1845) was most common. Small *Phidippus* nymphs taken throughout the study were identified to genus only

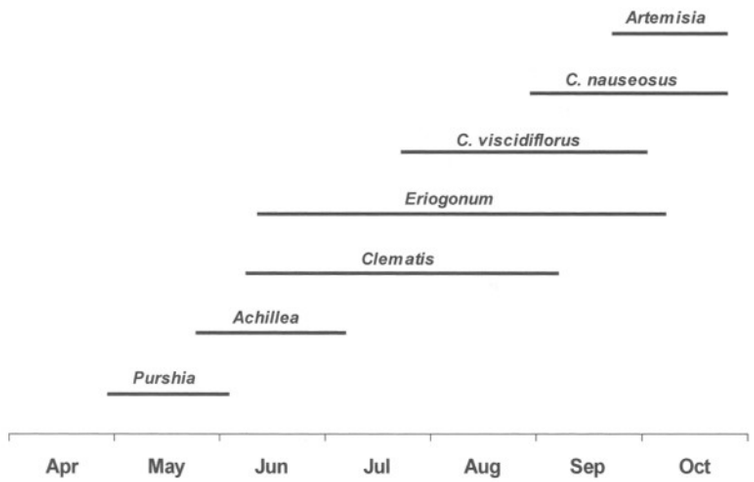

Figure 2. Flowering periods of the seven sagebrush steppe plants.

because of their similarity in appearance. Four other spiders, *Sassacus vitis* (Cockerell, 1894), *S. papenhoei*, *Philodromus insperatus* Schick, 1965, and *O. scalaris*, were also common on *Clematis*. *Orius tristicolor* was the most abundant predatory insect (Table 2). Potential prey on *Clematis* included the western flower thrips, Miridae, Cicadellidae, and Pentatomidae.

Eriogonum elatum

Tall buckwheat is a perennial herb with flowering stalks that reach 1 m or more in height. It flowered from mid-June to mid-October, and at a given site plants in flower were present for nearly four months (Fig. 2). We collected 9,154 predators, and species with orchard associations made up 99% of the fauna. Spiders that were abundant on *E. elatum* included *S. papenhoei, Xysticus*, and *Misumenops*. Most *Xysticus* and *Misumenops* were immatures, but 22 of 23 *Xysticus* reared to adulthood proved to be *X. cunctator*, while all 14 *Misumenops* reared to adulthood were *M. lepidus*. *Xysticus* was present throughout flowering but was most abundant from mid-June to mid-August. Five female *M. lepidus* were collected prior to 31 July. Recently hatched *Misumenops* appeared in early July and immatures were abundant through much of August. A general increase in size was noted as the season progressed, and sub-adult males were present by late September. The predatory insect fauna of tall buckwheat was dominated numerically by *O. tristicolor* (8,138 specimens). *Orius* colonized *E. elatum* early in its flowering period and persisted until flowering ceased in mid-October. Nymphs were present by mid-June but were most abundant from late July to mid-September. Their numbers then declined and nymphs still present by October were mostly 5th (last) instars. Adult females dominated the mid-October collections. *Orius* appears to reproduce on *E. elatum* and may complete more than one generation on the plant. Potential prey insects on tall buckwheat included *F. occidentalis*, Cicadellidae, Miridae, and Pentatomidae. Dense colonies of Aphididae were often found on the flowering stalks below the inflorescences.

Chrysothamnus viscidiflorus

Green rabbitbrush flowered from late July or early August to mid-September or early October, depending upon year and site. Predators were abundant, particularly during flowering, and 2,676 spiders and insects were collected. Arthropods representing species also found in orchards comprised 85% of the predators taken on *C. viscidiflorus*. *Misumenops lepidus* was the most common spider and specimens were present in virtually every collection. Eleven individuals were reared to adulthood. Other common spiders included *S. papenhoei* and immature *Pelegrina* (Table 1). *Orius tristicolor* was the most abundant predator (Table 2) and was especially abundant during flowering. Adults were the primary stage present early in the flowering period, but nymphs outnumbered adults during peak bloom before declining in number toward bloom's end. *Geocoris* spp. were fairly common on green rabbitbrush (*Geocoris atricolor* Montandon, 1908, *Geocoris pallens* Stal, 1854, and *Geocoris bullatus* (Say, 1832) are the principal local species) and three species of Coccinellidae with orchard associations were also collected. Potential prey included Thysanoptera, Miridae, Cicadellidae, Aphididae, Pentatomidae, and Lygaeidae.

Chrysothamnus nauseosus

Gray rabbitbrush is a perennial shrub that often occurs in association with big sagebrush. At a location where *C. viscidiflorus* and *C. nauseosus* co-occurred their flowering periods overlapped for most of September. Bloom began in late August or early September and was essentially completed by mid-October (Fig. 2). A total of 5,395 predators were collected on *C. nauseosus*. Numbers were highest during flowering and species known to occur in orchards made up 84% of the predator fauna. *Pelegrina helenae* (Banks, 1921) and *Philodromus histrio* (Latreille, 1819) were common spiders on *C. nauseosus*. Both species were regularly collected during flowering but were also found throughout July and August, well before bloom. *Misumenops lepidus* was taken almost exclusively during bloom, with fewer than 3% of the specimens obtained in the 31 pre-bloom samples of July and August. *Orius tristicolor* was collected primarily during the flowering period (only 30 of 3,417 individuals were taken before bloom). Adults dominated flowering period collections and comprised 84% of the individuals. Most nymphs (86%) were 4th and 5th instars. Species of Coccinellidae and Neuroptera known to occur in orchards comprised less than 1% of predatory arthropods (Table 2). Common potential prey insects included Thysanoptera, Aphididae, Cicadellidae, Miridae, Pentatomidae and Lygaeidae.

Artemisia tridentata

Big sagebrush was the last of the seven plants to flower and did so from late September to late October (Fig. 2). The natural enemy fauna of *A. tridentata* included many of the same species found on *C. nauseosus*. However, the number of natural enemies collected in bloom period samples on big sagebrush was much lower than on gray rabbitbrush: means of 50.1 vs. 121 per sample respectively, exclusive of parasitoids. This difference was due primarily to the lower numbers of *O. tristicolor* and *M. lepidus* collected on big sagebrush. A total of 1,947 spiders and insect predators was taken on *A. tridentata* and representatives of species also found in orchards made up 49% of the collections. Nearly 18% of the predatory arthropods (32% of spiders) collected on *A. tridentata* were *P. helenae*, a species found on the plant throughout the season. As on gray rabbitbrush, *M. lepidus* and *O. tristicolor*

Table 3. Insect parasitoids collected on seven sagebrush steppe plants.

Parasitoid family	*Purshia*	*Achillea*	*Clematis*	*Eriogonum*	*C. viscidiflorus*	*C. nauseosus*	*Artemisia*	Totals
Bethylidae	6	2		5	9	4	5	31
Dryinidae							3	3
Ichneumonidae	15			2		4	2	23
Braconidae	9	6	3	10	4	41	157	230
Charipidae	3				40	32	62	137
Eucoilidae				1		2		3
Figitidae						1		1
Diapriidae	1							1
Scelionidae	64	33	10	33	128	87	43	398
Platygastridae	20	3	1	30	365	1385	480	2,284
Ceraphronidae	1			9	10	4		24
Megaspilidae							1	1
Encyrtidae	168	6	8	64	190	98	38	572
Eulophidae	217	34	12	106	301	333	196	1,199
Pteromalidae	42	33	6	9	128	248	495	961
Aphelinidae	3		1					4
Torymidae	1					12	2	15
Eupelmidae	1	2			4	3		10
Eurytomidae	1	12	1	1	1	23	2	41
Eucharitidae	1			5	1			7
Chalcididae				2	1			3
Elasmidae				2		1		3
Trichogrammatidae				1		2		3
Mymaridae	1	1		1	2	2	6	13
Tachinidae	2					1		3
Total specimens	556	132	42	281	1,184	2,283	1,492	5,970
No. of families	18	10	8	16	14	19	14	25
No. of collections	65	20	12	64	43	71	77	352

were found on big sagebrush almost exclusively during bloom. By that time of year most *M. lepidus* were immatures of medium or large size, and most *O. tristicolor* were adults. Orchard associated Coccinellidae and Neuroptera were relatively well represented. Taxa of potential prey included Miridae, Aphididae, Cicadellidae, Pentatomidae, Lygaeidae, Psyllidae, Thysanoptera, and larval Lepidoptera.

Parasitoids

Parasitoid wasps comprised 30%, 31%, and 43% of all natural enemies collected on *C. nauseosus, C. viscidiflorus*, and *A. tridentata*, respectively and were particularly abundant during bloom. They were also common on *P. tridentata* (29% of natural enemies) but were more evenly distributed across the season and were most abundant in September (2003 data), well after bloom. Parasitoids comprised <10% of the natural enemy faunas of the other three plants. Twenty-four families of Hymenoptera were collected (Table 3). Platygastridae were the most numerous and were found on all seven plants, although only a single specimen was taken on *E. elatum*. Scelionidae, Braconidae, Encyrtidae, Eulophidae, Pteromalidae, and Eurytomidae were also collected on all seven plants. Dipterous parasitoids were

Table 4. Mean numbers of total natural enemies, orchard-associated predators, other predators, and parasitoids collected per sample on the four native shrubs during the pre-flowering, flowering, and post-flowering periods.

Plant stage	No. of samples	Total natural enemies	Orchard-associated predators	Other predators	Parasitoids
Purshia tridentata					
Pre-flowering	3	5.7	2.3	2.7	0.7
Flowering	17	23.0	7.8	9.4	5.8
Post-flowering	46	32.3	17.8	4.8	9.7
Chrysothamnus viscidiflorus					
Pre-flowering	6	12.2	6.2	5.5	0.5
Flowering	33	110.2	65.3	10.8	34.2
Post-flowering	4	30.3	20.3	0.5	9.5
Chrysothamnus nauseosus					
Pre-flowering	31	26.1	9.0	13.2	3.8
Flowering	37	176.7	108.6	12.2	55.9
Post-flowering	3	105.7	78.0	4.3	23.3
Artemisia tridentata					
Pre-flowering	62	32.6	7.6	11.8	13.2
Flowering	13	91.8	33.2	16.9	41.7
Post-flowering	2	114.0	47.5	4.0	62.5

rarely taken on any species (Table 3). None of the parasitoids were of known importance in orchard biological control.

Natural enemy abundance: flowering vs. non-flowering periods

The mean number of natural enemies per sample on the late-flowering *C. viscidiflorus, C. nauseosus*, and *A. tridentata*, was three to nine times higher during the flowering period compared to the pre-flowering period (Table 4). This difference was especially evident in predators that also occur in orchards and in parasitoids (Table 4). Although only a few post-bloom samples were taken on these three late-flowering species, natural enemy numbers declined markedly on *C. nauseosus* and *C. viscidiflorus* and showed a modest increase on *A. tridentata*. The increase in natural enemies on the three shrubs during flowering was particularly evident for the bug *O. tristicolor* and the spider *M. lepidus. Orius tristicolor* numbers rarely exceeded ten per sample during the pre-bloom period, and often none were taken. In contrast, flowering period samples from *C. nauseosus* and *C. viscidiflorus* usually yielded 25 to 150 specimens and twice exceeded 300. *Misumenops lepidus* was also infrequently taken in pre-bloom collections whereas flowering period samples yielded 1 to 25 specimens, occasionally more. Few samples were taken on *Purshia tridentata*, the first species to flower, during the pre-bloom period. A several fold increase in natural enemies was noted as *Purshia* came into flower, and the increase continued during the post-flowering period. Mean number of natural enemies per sample during flowering was 23 compared to 32 in the post-bloom period (Table 4). Even late in October natural enemies were quite abundant on *P. tridentata. Orius* and *Misumenops*, which were uncommon during bloom, were most abundant from mid-September through October, although numbers were much lower than on the two *Chrysothamnus* species during the same period.

Discussion

The arthropod communities on each of the seven plant species that were monitored in this study included large numbers of spiders and predatory insects. This finding has implications in orchard pest management because many of these natural enemies are species that are also found in neighboring pear and apple orchards (Miliczky et al. 2000, Miliczky & Horton 2005, unpublished data). A number of the predator species that occur on both sagebrush steppe plants and fruit trees are known or inferred to feed on pest arthropods in orchards (Beers et al. 1993, personal observations). Olszak et al. (1992) found that an apple orchard and the shrubs surrounding it shared many spider species. The shared species made up high percentages of the orchard spider fauna and the faunas of each of the nearby shrubs. Chant (1956) worked in both insecticide-treated and untreated orchards. He found a high degree of similarity between the spider faunas of treated orchards and the faunas of the immediately surrounding habitats. The spider faunas of untreated orchards, however, showed much less similarity with the faunas of the surrounding habitats. The untreated orchards apparently supported many indigenous species.

Irrigated central Washington orchards and the dry, sagebrush steppe, differ in many characteristics, including availability of water, plant species composition, growth form of the dominant plants, nature of the ground cover, and availability of shade. While many predator species do occur in both habitats, several species common on sagebrush steppe plants were rare in the orchards. Two species common on native plants but rare in orchards were the spiders *Pelegrina helenae* and *Philodromus histrio*. Reasons for their absence from the orchards may be related to habitat and host plant preferences, because previous collections of both species have been from grassland and shrub dominated communities with many records from *Artemisia tridentata* (Cutler & Jennings 1985, Maddison 1996, Dondale & Redner 1978). Schick (1965) remarked on *P. histrio*'s close association with *A. tridentata*. The predaceous bug *Deraeocoris bakeri* Knight, 1921 was collected on all four shrubs but was not found in the orchards and may also be restricted to sagebrush steppe and other dry habitats (Razfimahatratra 1980). Duelli et al. (1990) studied movement of spiders and carabid beetles between natural and cultivated areas. Many species showed varying degrees of mobility between areas, but a few showed little tendency to move out of natural areas. Other factors that may influence the habitat in which a species occurs include specialization on certain prey and habitat specific mating, oviposition, or overwintering requirements (Letourneau 1998).

Several generalist predators that have elsewhere been reported to be of some importance in orchard biocontrol were not found in our study orchards except in incidental numbers, despite extensive collecting since 1996. These species were not included among the species with orchard associations in this report. Examples include snakeflies (Raphidiidae) and assassin bugs (Reduviidae), both of which have been reported as predators in Northwest orchards (Beers et al. 1993). *Anthocoris whitei*, abundant on bitterbrush during this study, may be abundant on pear in southern Oregon, at least in some years (Westigard et al. 1968) but locally has been reported in low numbers only (Horton & Lewis 2000). These and certain other species may be more common orchard inhabitants in other regions.

The orchard consists of a number of habitats: trees, understory vegetation, and ground surface. Each habitat's natural enemy fauna consists of species that are largely restricted to it and species that also occur in one or more of the other habitats

(Miliczky et al. 2000). Natural enemy species found in the trees may be the most likely to contribute to orchard pest control, but natural enemy species in the other habitats will also contribute if pest species move out of the trees. Many of the spiders that were found in both the sagebrush steppe and the orchards are known to occur in the orchard canopy. *Sassacus papenhoei, O. scalaris, X. cunctator, M. lepidus, M. fillmorana*, and *Theridion neomexicanum* Banks, 1901 made up 2% to 13% of the arboreal spider fauna in the organic apple and pear orchards studied by Miliczky et al. (2000). Other species, although more typical of the understory or orchard floor, occasionally find their way into the trees, e.g., *Tibellus oblongus* (Walckenaer, 1802), *Erigone dentosa* O. P.-Cambridge, 1894, and *Tetragnatha* (Miliczky et al. 2000). The same is true of the predatory insects. *Deraeocoris brevis* (Uhler, 1904), *Campylomma verbasci* (Meyer-Dur, 1843), *Chrysopa nigricornis* Burmeister, 1839, *Chrysopa coloradensis* Banks, 1895, and several of the ladybeetles are important arboreal species. *Geocoris* spp. and *Nabis alternatus* Parshley, 1922, although more frequent in the understory or orchard floor, do ascend the trees on occasion (Beers et al. 1993, Flint & Dreistadt 1998, unpublished data).

The increase in natural enemies collected on the plants during flowering was probably related to the presence of a greater variety and number of potential prey insects seeking pollen and nectar from the flowers. Not all natural enemies showed such an increase, but of those that did *Orius tristicolor* was likely responding to large numbers of western flower thrips, an important prey species. Flower thrips can be found on virtually any local plant species while in flower, sometimes in very large numbers (unpublished data). *Misumenops lepidus* numbers were also high on several of the plants during bloom, and flowers are a preferred hunting site for this spider (Dondale & Redner 1978). We inferred that to some extent at least, *Orius* and *Misumenops* were moving among plants as successive species came into flower.

In summary, several native plants of the sagebrush steppe in south-central Washington were found to support diverse and abundant natural enemy faunas, a substantial proportion of which consisted of spiders and predatory insects that also occur in local orchards. These species may contribute to biological control of orchard pests. Undisturbed, native habitat adjacent to an orchard may thus benefit pest control in orchards if natural enemies from the native habitat move into the crop, which seems likely (Miliczky & Horton 2005). Conservation of native habitat when it is present near orchards or other cropland may be worthwhile because of its potential contribution to biological control within the crop.

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